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Short-Term Battlescale Forecast Model Performance Incorporating Utah Mesonet Stations

by Barbara Sauter and Teizi Henmi

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Short-Term Battlescale Forecast Model Performance Incorporating Utah Mesonet Stations

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Preface

The Battlescale Forecast Model (BFM) is a mesoscale weather forecast model used in operational support to the U.S. Army. The U.S. Army requires information on the ground where soldiers and equipment operate in a wide variety of locations and conditions. The BFM can incorporate surface observations from the region of interest, but such observations are usually not available at remote areas encompassing complex terrain. This study examines the value of initializing the BFM with surface observations from the MesoWest cooperative, over an area of widely varying terrain near Salt Lake City, Utah.

The authors acknowledge the invaluable assistance of Mr. Robert Flanigan of the U.S. Army Research Laboratory. Because of his knowledge and support with computer and file settings, the model runs used in this study were performed much faster than would otherwise have been possible.

Executive Summary

Overview

The primary purpose of this study is to examine whether or not incorporating observations from surface stations in a mesoscale weather forecast model will produce more accurate forecasts over an area of highly varying terrain. The model used in the study is the Battlescale Forecast Model (BFM), which was run over an area 125 by 125 km near Salt Lake City, Utah. Data from numerous surface station observations are available at diverse locations within this model domain from the Utah mesonet stations obtained through the University of Utah MesoWest cooperative. The model was initialized with a large-scale model providing boundary conditions, along with a single upper-air sounding, with runs performed for 32 days during the winter and 16 days during the spring of 2002. The model was initialized at 3-h intervals from 00Z through 18Z each day, with each model run producing hourly output from the 0 h through a 6-h forecast. Runs were performed that included up to 20 surface station observations in the model initialization, along with equivalent runs done with no surface data in the initialization. The results of all the forecast model runs were compared to surface station observations from up to 76 locations, although only approximately one-half of the stations were available at any particular validation time. The statistics from these comparisons were aggregated for the runs using surface data and also for the runs without surface data. Results are provided in the form of mean error, absolute error, and correlation coefficient values by forecast hour for all the winter model runs, and separately for the springtime runs.

Conclusions

The results from this particular study strongly indicate that the addition of multiple surface observations in the BFM initialization usually do not significantly improve the resulting weather forecast over this complex domain in Utah. There are instances within these cases where the inclusion of surface data did increase the forecast accuracy substantially, and these conclusions should not be generalized to other times and locations. A follow-up study is planned to investigate the amount of error that might be attributed to validating with observations at a single point-in-time rather than using short-term averages of the reported values, particularly for wind direction. Since the absolute error amounts of the temperature and wind direction forecasts often were not within the accuracy required by the U.S. Army, both with and without surface data in the model initialization, it does appear that further work is warranted in refining methods to provide accurate nowcasts or short-term forecasts over complex terrain.

1. Introduction

The U.S. Army requires accurate short-term weather forecasts in order to optimize the use of personnel and systems in mission execution in a wide variety of locations and conditions. One of the forecast models available on the battlefield is the Battlescale Forecast Model (BFM) [1], which is fielded as an element of the Integrated Meteorological System (IMETS). It provides forecasts of pressure, temperature, humidity, and winds, as well as many derived weather parameters out to 24 h. The purpose of this study is to investigate the performance of the BFM over an area of complex terrain, comparing results of model runs incorporating surface observations from Utah mesonet stations with results of equivalent model runs made without any surface data.

2. Model Setup

A previous study [2] provided evidence that the accuracy of nowcasts of basic weather parameters could be significantly improved through successive corrections using Oklahoma mesonet station observations each hour for that hour's nowcast. However, a scenario involving more complex terrain and a short-range forecast may be more applicable to many U.S. Army operations. Therefore, the BFM has been run as described below to investigate forecast accuracy at 0 to 6 h over the Salt Lake City, Utah area.

The BFM model domain centered at 40.5 degrees N 112.0 degrees W is shown in Figure 1. It is based on 51 by 51 grid points, with 2.5 km grid spacing between points, resulting in an area 125 km on each side. The model is initialized with digital terrain data at the 2.5 km grid spacing, along with a single upper-air sounding from Salt Lake City, and boundary conditions provided by the 00Z analysis and 12Z 12-h forecast field and subsequent 00Z 24-h forecast field of the Navy Operational Global Atmospheric Prediction System (NOGAPS) [3]. Surface observations used in the initialization and those used for validation were obtained from the University of Utah MesoWest cooperative [4,5]. Various organizations have responsibility for some of the surface stations. Although the instrumentation may not all be strictly within standard height and calibration guidelines, and not every station observation is available every hour, the data reliability is considered acceptable. The 20 stations chosen for model initialization were more consistently available than many of the other stations. These stations are also included in the verification statistics, which are based on all the stations available at each particular verification time, ranging from approximately 30 stations to all 76 stations. Table 1 displays the wide range of elevation represented by the surface station observations used both for initialization and verification. (See Appendix A for station data.)

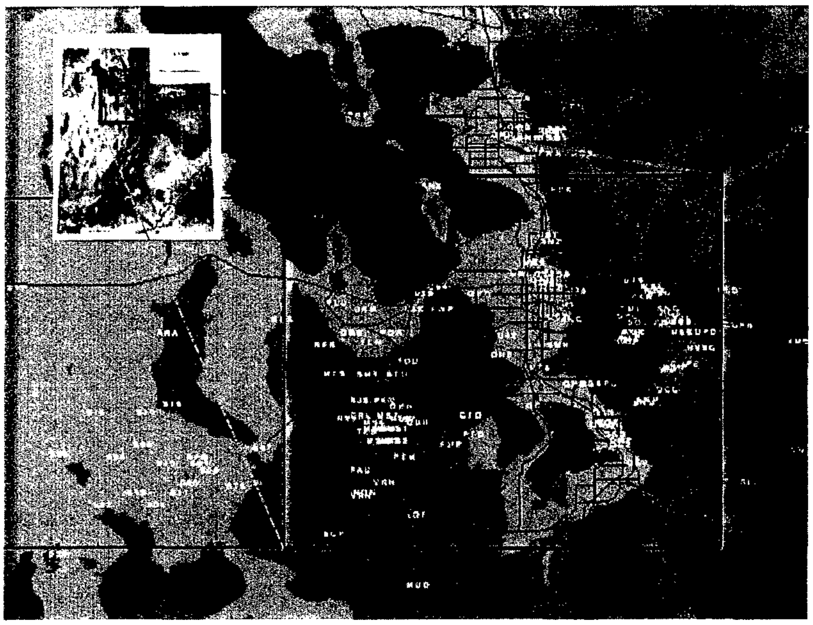

Figure 1. Model domain over north central Utah.

Table 1. The number of stations at various elevations in the model domain.

Station Elevation (Feet)	No. of Stations Used in Model Initialization	No. of Stations Used in Model Verification
4000-5000	8	33
5000-6000	5	22
6000-7000	1	6
7000-8000	2	3
8000-9000	1	5
9000-10000	3	6
10000-10500	0	1

BFM runs were performed for 32 winter days between January 15 and March 14, 2002 and 16 spring days between April 17 and May 23, 2002. Each run generated hourly output interpolated to the 76 verification station locations at 7 times from the 0 h to a 6-h forecast. These forecasts were initialized at 3-h intervals from 00Z through 18Z each day. The 00Z, 03Z, 06Z, and 09Z runs were initialized with fields valid at

- 00Z from the NOGAPS 00Z analysis field and the 00Z Salt Lake City upper-air sounding
- 12Z from the NOGAPS 12-h forecast field
- 00Z the following day from the NOGAPS 24-h forecast field

The 12Z, 15Z, and 18Z runs were initialized with fields valid at

- 12Z from the NOGAPS 12-h forecast field and the 12Z Salt Lake City upper-air sounding
- 00Z the following day from the NOGAPS 24-h forecast field

Each run was performed initially without any surface station data, then rerun using up to 20 surface station observations at the 0 h initialization time only.

3. Results

The primary purpose of this study was to determine the value of the surface observations in producing more accurate forecasts of basic weather parameters over complex terrain. This was accomplished by investigating the impact of incorporating Utah mesonet station data in the initialization of the BFM. However, the results will also be discussed in terms of general accuracy of the model in this area. Since the forecast accuracies from the winter cases displayed some unusual tendencies, another set of runs was performed in the spring to see if the evaluations were comparable. The number of days available to run the model for the spring was only one-half the number used in the winter runs, and is less than would be preferred.

The overall accuracy of all the model runs is plotted as mean error, absolute error, and correlation coefficient timelines in Appendix B. Bar graphs depicting the difference between model runs initialized with surface observations and those initialized without surface observations are provided in Appendix C. Samples of these charts are also included in the discussion below.

3.1 Temperature Results

The U.S. Army has stated a requirement for the accuracy of temperature forecasts to be within 1 degree C [6]. The hourly nowcasts generated over Oklahoma using surface mesonet station observations were generally able to meet that requirement [2]. This was not the case in these short-term forecasts over the highly variable terrain in Utah, which contained mean absolute

errors around 2 degrees C in the winter and 3 degrees C in the spring during the nighttime hours and usually somewhat higher errors during daylight hours.

The timelines showing temperature bias for the winter runs are shown in Figure 2. Solid lines are for the BFM using surface data from up to 20 Utah mesonet stations, with dashed lines for the BFM with no surface data used. The corresponding dashed lines are frequently obscured by the solid lines, since the differences are so small at those points. The model runs initialized at 03, 06, and 09Z have the strongest warm bias at the 0 h, with a lesser warm bias in subsequent hours of the forecast. The model runs initialized at 12 and 15Z reveal a significant 2 to 3 degrees C warm bias throughout the model run. On the other hand, the model runs initialized at 00 and 18Z actually reflect a slight cool bias at the 0 h. The remaining forecasts for those hours revert to a slight warm bias, other than the 5th hour of the 18Z forecast, which once again decreases to a small cool bias.

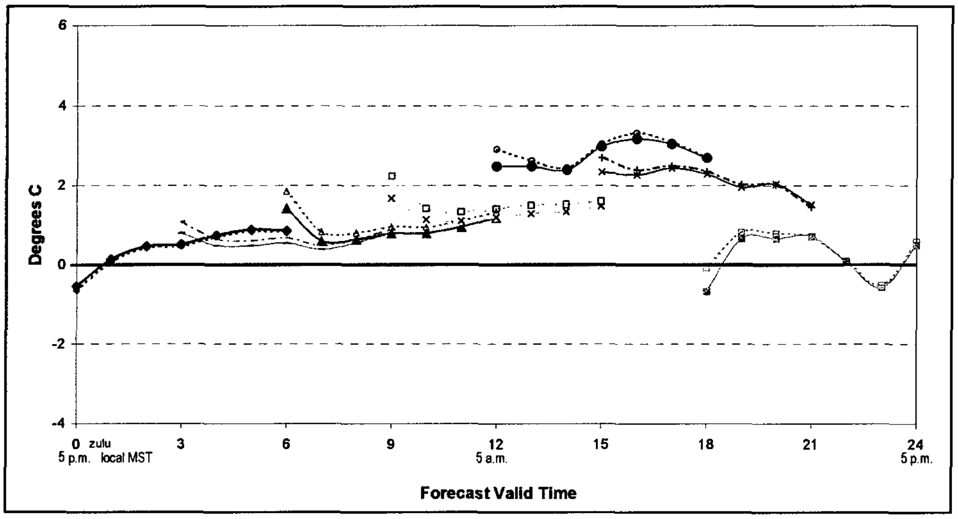

Figure 2. Temperature mean errors in winter model runs.

The temperature bias timelines from the spring model runs (Fig. 3) are quite different from those for the winter. The forecast model runs initialized at 00, 03, 06, and 09Z generally reflect a 2 degrees C cool bias at the 0 h, progressing to smaller bias amounts throughout the following forecast valid times, reaching close to no bias at the 6-h forecast. The 12Z run starts with a small warm bias, which grows to a 1 to 2 degrees C warm bias as the forecast progresses out in time. Similar traits are found in the 15Z run, except that its 0-h forecast starts out with a 1 degree C cool bias with the remaining forecast times containing a 1 to 2 degrees C warm bias. Possibly the oddest model run temperature forecast results are found in the spring runs initialized at 18Z, where the 0 and 6-h forecasts each include a greater than 3 degrees C cool bias, while the intervening hours generally include a 1 degree C warm bias. It can be concluded that the total range of error in these 18Z springtime temperature forecasts includes a great deal of variation in too warm and too cool temperatures at different stations and different dates, since the absolute errors in these runs are greater than 4 degrees C. The particularly large bias at the 0 h of the 18Z

forecast appears to be related to the model, since the 3-h forecast from the 15Z model run that is valid at the exact same time does not reflect this bias.

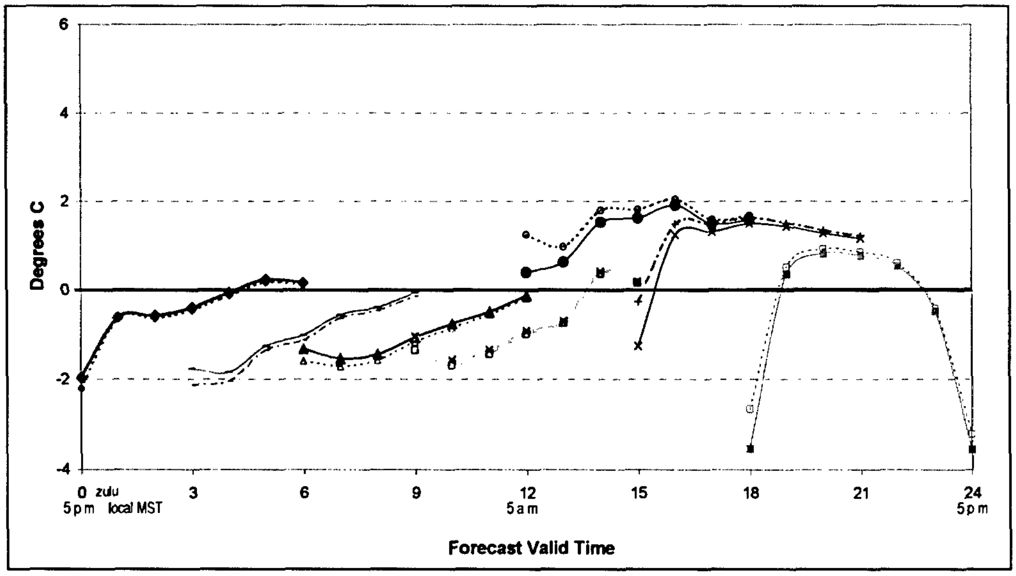

Figure 3. Temperature mean errors in spring model runs.

As noted, the differences between the model runs using surface observations for initialization and those without any surface data are generally quite small compared to the overall forecast error amounts. The greatest improvement in temperature forecast accuracy based on the inclusion of surface data from Utah mesonet stations occurs at the 0 h, particularly for the model runs initialized at 03, 06, and 09Z, which increase the temperature forecast accuracy by approximately 0.5 degrees C. The 2 times with the large cool temperature bias discussed above at the 0 and 6-h forecasts of the 18Z run actually show a significant decrease in temperature forecast skill after incorporating the surface data into the model initialization. Use of the surface observations also results in a slight decrease in forecast accuracy at some of the other forecast times in the 15 and 18Z model runs. Otherwise, most forecast valid times contain a slight improvement in temperature forecasts when surface data are used in the model initialization, but the improvement is small compared to the overall forecast error.

3.2 Dew-point Temperature Results

The dew-point temperature errors are generally greater than the temperature errors, but are most often in the same direction as the temperature error, so that the relative humidity forecasts are somewhat better than would be indicated solely by evaluating the dew-point temperature bias and total error amounts. The most noticeable trait of the dew-point temperature error timeline charts are the wave-like plots, reflecting hour-to-hour increases or decreases in the error amount, rather than the expected smooth progression of increasing error as the forecast time extends further out from the 0 to the 6-h forecast. This is shown in Figure 4. Note that the Y-axis uses a different range than the one used in the equivalent chart for temperature shown in Figure 2.

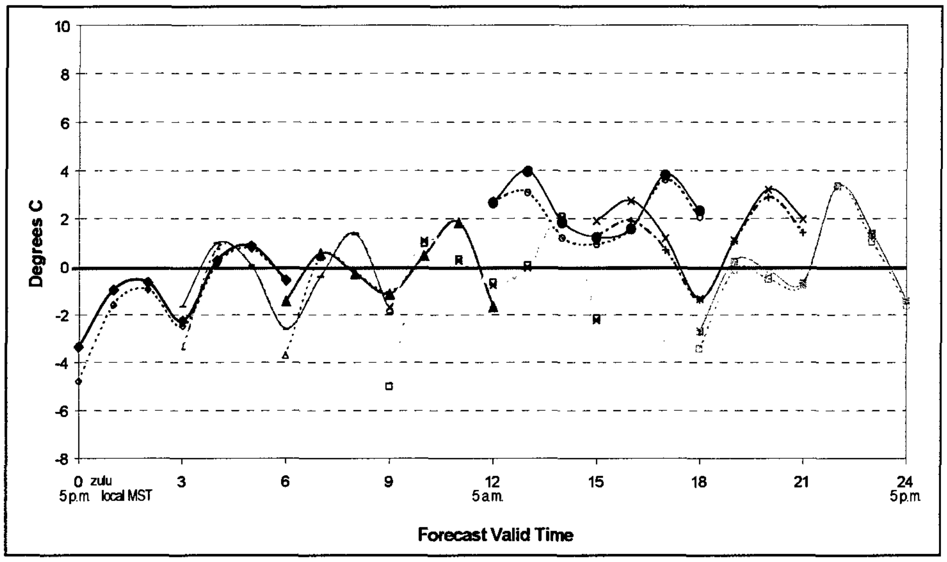

Figure 4. Dew-point temperature mean errors in winter model runs.

Further investigation will be required to determine the source of the wave patterns in the dew-point temperature error timelines. The output files saved from these model runs contain the value of relative humidity, but not dew-point temperature explicitly. Averaging the observations over the model domain for each hour to try to determine a pattern is not applicable, since different stations report from one hour to the next. A quick look at the observed dew-point temperatures for a few individual stations, as plotted in Figure 5, may indicate somewhat of a wave pattern in the raw observed dew-point temperature values for a single date. However, this sample is much too small to draw any conclusions.

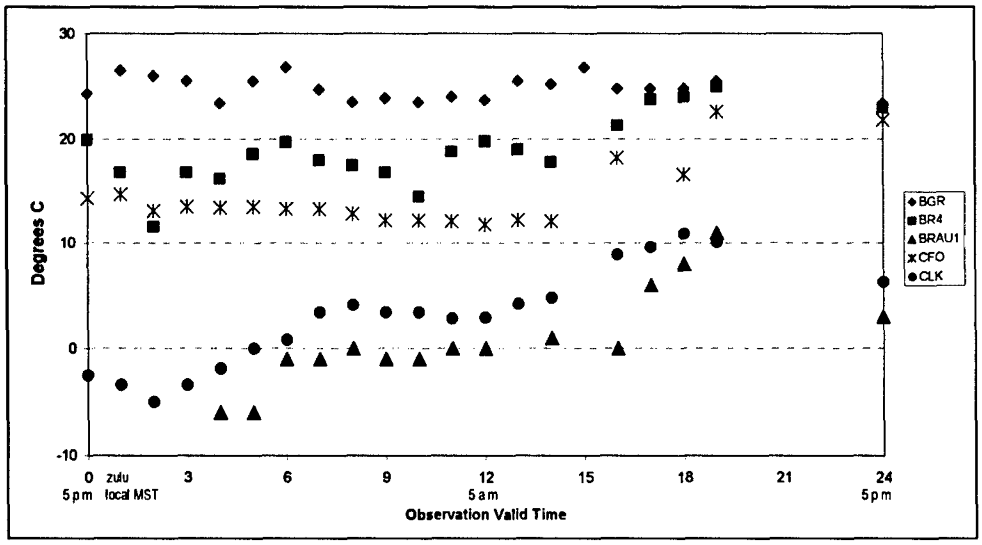

Figure 5. Observed dew-point temperatures for a small sample of stations on January 15, 2002.

The 0-h forecast of dew-point temperatures shows a significant improvement when surface observations are included in the 00, 03, 06, and 09Z model runs, reaching 1.5 to more than 2 degrees C improvement in the winter runs, and around 1 to 1.5 degrees C in the spring runs. The increase in accuracy drops progressively through forecast hours 1 through 6, with no significant improvement by hour 3 in both the winter and spring runs. On the other hand, as can be seen in Figure 6, many of the dew-point temperature forecasts in the runs initialized at 12, 15, and 18Z actually get worse when surface observations are incorporated in the initialization.

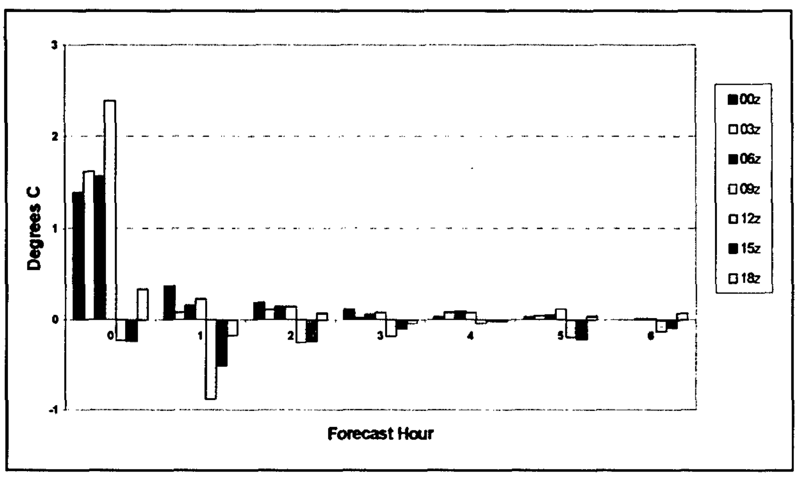

Figure 6. Increase in dew-point temperature accuracy using surface observations in winter model runs.

3.3 Wind Results

The results of these model runs, over highly variable terrain, provided wind speed forecasts generally within the U.S. Army's stated accuracy requirement of 5 knots, but substantially failing to meet the goal of 5 degrees for wind direction [6]. These requirements would probably be more realistic stated as a percentage value for higher wind speeds, and some of the error may be related to the validations being performed against observations at a point-in-time rather than averaging the surface station data over time. It is clear, however, that methods to improve short-term wind forecasts at specific complex and remote locations would be of great value to the U.S. Army.

The u and v wind component errors behave reasonably as expected over the model run extending from the 0 to a 6-h forecast, with error amounts remaining fairly constant or increasing as the forecast goes out in time. An exception to this trend occurs for the u wind component at the validation time of 15Z in both the model runs performed with no surface observations included in the initialization at 12 and 15Z. This anomaly appears in both the winter and the spring runs. The unusually large error present at that time compared to the preceding and subsequent hours in these cases does not occur in the equivalent model runs that use surface data in their initialization, as shown in Figure 7.

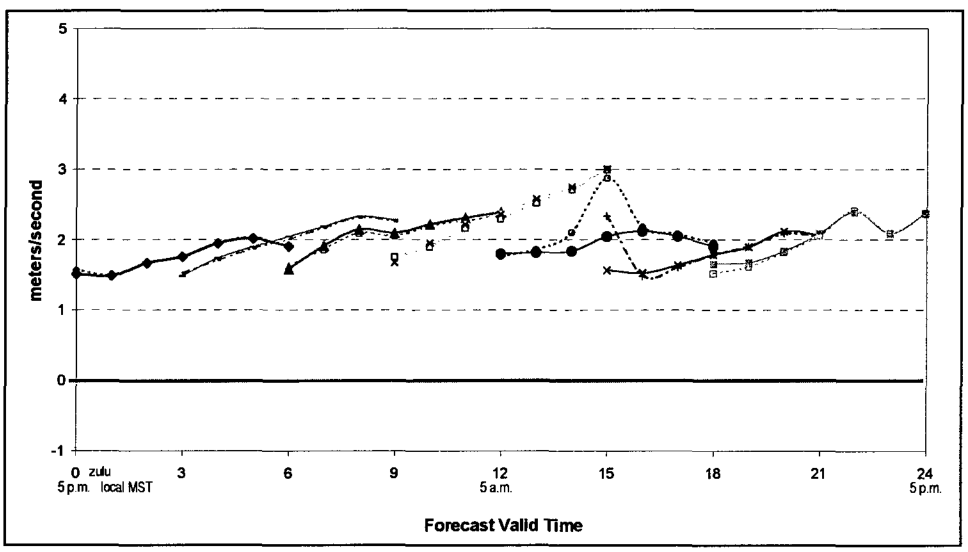

Figure 7. U Wind component absolute errors in winter model runs.

The bias in wind speed forecasts in the winter runs is primarily within 0 to 0.5 m/s too weak, with the absolute error ranging between 1.5 to 2 m/s. The exception relating to the u wind component error discussed above occurs at 15Z in the runs without surface data, where the wind speed shows a bias to be about 0.5 m/s too strong, and an absolute error amount reaching 2.5 m/s. The wind speed errors in the spring display a significantly different trait in the 00, 03, and 06Z runs, which start out similarly to the winter results at the 0-h forecast. The weak bias is

a little more pronounced in the spring. After that time, however, the spring runs show a progressive increase in forecasted wind speeds compared to the observed wind speed through the 4-h forecast in the 00Z run and through the final 6-h forecast in the 03 and 06Z runs. These wind speed forecasts reach a 2 m/s high bias and absolute errors of 3.5 m/s.

The majority of wind direction errors range between 50 and 60 degrees. As seen in Figure 8, even in the cases where initializing with surface observations improves the wind direction forecast, the amount of the improvement up to 5 degrees is not sufficient to meet the U.S. Army's desire for accurate wind direction forecasts.

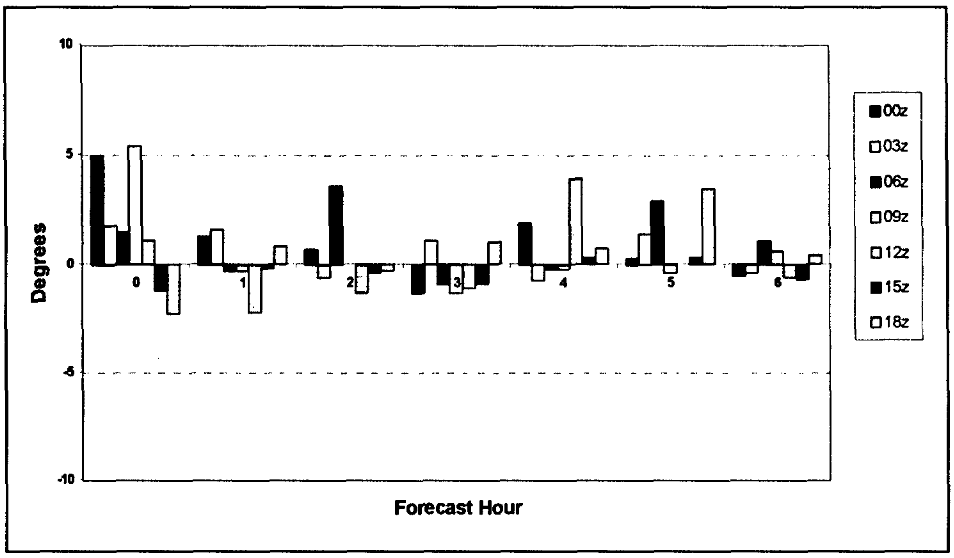

Figure 8. Increase in wind direction accuracy using surface observations in winter model runs.

4. Conclusions

As automated processes become more prevalent on the battlefield, and the output of weather forecast models drives multiple applications, the accuracy of such forecast data becomes more important. The BFM and other existing models provide the necessary raw data appropriate for many military planning and mission execution purposes in various locations around the world. Increasing employment of smart systems and smaller, lighter warfighting capabilities is driving the need for more accurate short-term, point-specific weather information, which is particularly difficult to determine over areas of complex terrain. The availability of MesoWest surface station data, over a complex region in Utah, enabled this study to investigate the value of including more surface station observations in the BFM initialization and to perform validations at many more diverse locations than would normally be available.

The results from this particular study strongly indicate that the addition of multiple surface observations in the BFM initialization usually do not significantly improve the resulting weather forecast over this complex domain in Utah. There are instances within these cases where the inclusion of surface data did increase the forecast accuracy substantially, and these conclusions should not be generalized to other times and locations. A follow-up study is planned to investigate the amount of error that might be attributed to validating with observations at a single point-in-time rather than using short-term averages of the reported values, particularly for wind direction. Since the absolute error amounts of the temperature and wind direction forecasts often were not within the accuracy required by the U.S. Army, both with and without surface data in the model initialization, it does appear that further work is warranted in refining methods to provide accurate nowcasts or short-term forecasts over complex terrain.

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Appendix A. Mesowest Stations Used in Short-Term Battlescale Forecast Model Performance Study

This appendix is part of ARL-TR-2810, U.S. Army Research Laboratory, White Sands Missile Range, NM 88002-5501.

Table A-1. Mesowest surface station information for stations used in this study.

see note	ID	NAME	LAT	LONG	ELEV	TYPE
	AFOR	AMERICAN FORK JH UT	40.37	-111.78	4600 ft	AWS
	ALT	ALTA - GERMANIA UT	40.57	-111.63	10443 ft	AVALANCHE
	BAC	BACCUS/SR111 UT	40.63	-112.06	5172 ft	UTAH DOT
	BBN	BOUNTIFUL BENCH UT	40.89	-111.85	4990 ft	KSL
	BCP	BLACK CROOK PEAK UT	39.96	-112.52	9275 ft	TOOELE
*	BGR	BADGER ISLAND UT	40.94	-112.56	4199 ft	SNOWNET
	CFO	CEDAR FORT UT	40.31	-112.1	5200 ft	TOOELE
	CLK	CANYONS - LOOKOUT UT	40.68	-111.57	8297 ft	SNOWNET
	CRL	CLOVER-RUSSELL LANE UT	40.33	-112.44	5161 ft	TOOELE
	CUPC	UTAH LAKE - SARATOGA UT	40.36	-111.9	4495 ft	CUP
	CUPD	JORDANELLE DAM UT	40.6	-111.42	6086 ft	CUP
	CUPE	SNAKE CREEK-CHARLESTON UT	40.49	-111.47	5430 ft	CUP
	CUR	MERCUR CANYON UT	40.31	-112.27	5741 ft	TOOELE
*	DCC	DEER CREEK DAM CHUTE UT	40.43	-111.54	6670 ft	AVALANCHE
*	DVB	DV - BALD EAGLE UT	40.62	-111.48	8501 ft	SNOWNET
	DVE	DV - BURNS UT	40.62	-111.45	7333 ft	SNOWNET
	EMP	DV - EMPIRE PK UT	40.61	-111.53	9570 ft	SNOWNET
	FAU	FAUST-CLELL LEE UT	40.17	-112.43	5322 ft	TOOELE
	FFD	FAIRFIELD UT	40.26	-112.09	4902 ft	TOOELE
*	FLU	FLUX UT	40.69	-112.51	4219 ft	TOOELE
*	FMP	FIVE MILE PASS UT	40.23	-112.18	5381 ft	TOOELE
*	FPK	FRANCIS PEAK UT	41.03	-111.84	9560 ft	SNOWNET
*	FWP	FARNSWORTH PEAK UT	40.66	-112.2	9176 ft	SNOWNET
	GRS	GRANTSVILLE UT	40.59	-112.47	4465 ft	TOOELE
	HGLD	LONE PEAK HS UT	40.38	-111.77	4564 ft	AWS
	HOL	NORTH HOLLADAY UT	40.68	-111.83	4600 ft	SNOWNET
*	HQ2	REGION 2 HEADQUARTERS UT	40.73	-111.96	4167 ft	UTAH DOT
	LAK	LAKE POINT UT	40.67	-112.28	4259 ft	TOOELE
	LDS1	LDS CHURCH OFFICE UT	40.77	-111.89	4757 ft	SNOWNET
*	LOF	LOFGREEN UT	40.02	-112.27	5801 ft	TOOELE
	MBY	DV - MOUNT BALDY UT	40.61	-111.48	9347 ft	SNOWNET
	MSI01	SUGARHOUSE - MSI UT	40.72	-111.86	4400 ft	MSI
	MTB	MORMON TRAIL BAR UT	40.46	-112.52	5400 ft	TOOELE

Note: Stations preceded by an asterisk in the left column were used for BFM surface observation initialization.

see note	ID	NAME	LAT	LONG	ELEV	TYPE
	NSLT	ORCHARD ELEM SCHOOL UT	40.85	-111.92	4701 ft	AWS
	OPH	OPHIR STATION UT	40.36	-112.32	5561 ft	TOOELE
	ORMU	NORTHRIDGE ELEM SCHOOL UT	40.32	-111.68	4770 ft	AWS
	PAYS	PAYSON JH UT	40.03	-111.72	4757 ft	AWS
	PCB	PARK CITY - BASE UT	40.65	-111.51	6562 ft	SNOWNET
	PCS	PARK CITY - EAGLE UT	40.65	-111.52	8563 ft	SNOWNET
	PEM	PONY EXPRESS MARKER UT	40.21	-112.29	5098 ft	TOOELE
*	PEN	PENNYS UT	40.39	-112.39	5121 ft	TOOELE
	PGJH	PLEASANT GROVE JH UT	40.37	-111.73	4619 ft	AWS
	POR	ERDA AIRPORT UT	40.6	-112.35	4360 ft	TOOELE
	PROU	BRIGHAM YOUNG UNIVSITY UT	40.25	-111.65	4665 ft	AWS
	QLN	LINDON UT	40.34	-111.71	4760 ft	AQ
	RES	GRANTSVILLE RESERVOIR UT	40.55	-112.55	5479 ft	TOOELE
*	RVF	RUSH VALLEY FIRE STN UT	40.32	-112.48	5341 ft	TOOELE
	SJS	ST. JOHN SUBSTATION UT	40.38	-112.44	5036 ft	TOOELE
	SMT	SOUTH MOUNTAIN UT	40.46	-112.42	6001 ft	TOOELE
	SNC	PARK CITY MUN G.C. UT	40.66	-111.51	6355 ft	SNOWNET
	SND	SUNDANCE - ARROWHEAD UT	40.37	-111.59	8251 ft	AVALANCHE
	SNH	SANDY HOREL/U UTAH UT	40.55	-111.85	4757 ft	SNOWNET
	SNL	SLC NWSFO RAD UT	40.77	-111.96	4239 ft	SNOWNET
*	SNX	ANTELOPE ISLAND S.P. UT	41.04	-112.23	4199 ft	SNOWNET
	SNZ	BOUNTIFUL/F G HOUSE UT	40.88	-111.87	4760 ft	SNOWNET
*	SOL	SOLITUDE UT	40.61	-111.6	9888 ft	AVALANCHE
	STO	STOCKTON BAR UT	40.46	-112.33	5161 ft	TOOELE
*	TEN	TEAD NORTH UT	40.56	-112.41	4501 ft	TOOELE
	TES	TEAD SOUTH UT	40.28	-112.42	5141 ft	TOOELE
	TOO	TOOELE CITY UT	40.51	-112.3	5135 ft	TOOELE
*	TPC	TIMPANOGOS CAVE UT	40.44	-111.71	7999 ft	SNOWNET
	URM	BURMESTER UT	40.66	-112.43	4219 ft	TOOELE
	UT12	I15/I215 SB UT	40.64	-111.9	4407 ft	UTAH DOT
	UT20	I15 500S WB (Gateway) UT	40.76	-111.9	4400 ft	UTAH DOT
	UT23	I-15/2400 S Spaghetti UT	40.72	-111.9	4219 ft	UTAH DOT
*	UT5	MOUTH PARLEYS UT	40.71	-111.8	4915 ft	UTAH DOT
*	UT7	BLUFFDALE UT	40.48	-111.9	4700 ft	UTAH DOT
	UT9	LAKE POINT I-80 UT	40.69	-112.27	4301 ft	UTAH DOT
	VRH	VERNON HILL UT	40.13	-112.38	5761 ft	TOOELE
*	VRN	VERNON UT	40.09	-112.43	5561 ft	TOOELE
*	WBB	WBB/U UTAH UT	40.77	-111.85	4910 ft	SNOWNET
	WBE	WSP BOB LOWER UT	40.71	-111.56	6980 ft	SNOWNET
*	WBU	WSP BEAR UPPER UT	40.71	-111.56	7160 ft	SNOWNET
	WCR	WOLF CREEK RANCH UT	40.55	-111.32	8000 ft	SNOWNET
	WM2	Soldier Hollow Whales Tail UT	40.48	-111.49	5541 ft	SNOWNET
	WMP	SOLDIER HOLLOW UT	40.48	-111.5	5619 ft	SNOWNET

Appendix B. Timeline Charts of BFM Results Over the Salt Lake City Area Including up to Seventy-Six Utah Mesonet Stations

This appendix is part of ARL-TR-2810, U.S. Army Research Laboratory, White Sands Missile Range, NM 88002-5501.

Mean errors, absolute errors, and correlation coefficients are shown in Figures B-1 through B-12 for temperature, dew-point temperature, wind speed, u wind component, and v wind component, along with wind vector root mean square error and wind direction absolute errors.

Each solid line represents the seasonal statistics calculated from every station with an observation available for comparison with hourly forecast values for seven model run initialization times of 00, 03, 06, 09, 12, 15, and 18Z, initialized with up to 20 surface station observations.

Dashed lines are the equivalent results for model runs initialized with no surface station observation data. These lines are frequently obscured by overlaying the solid line, where no significant difference exists.

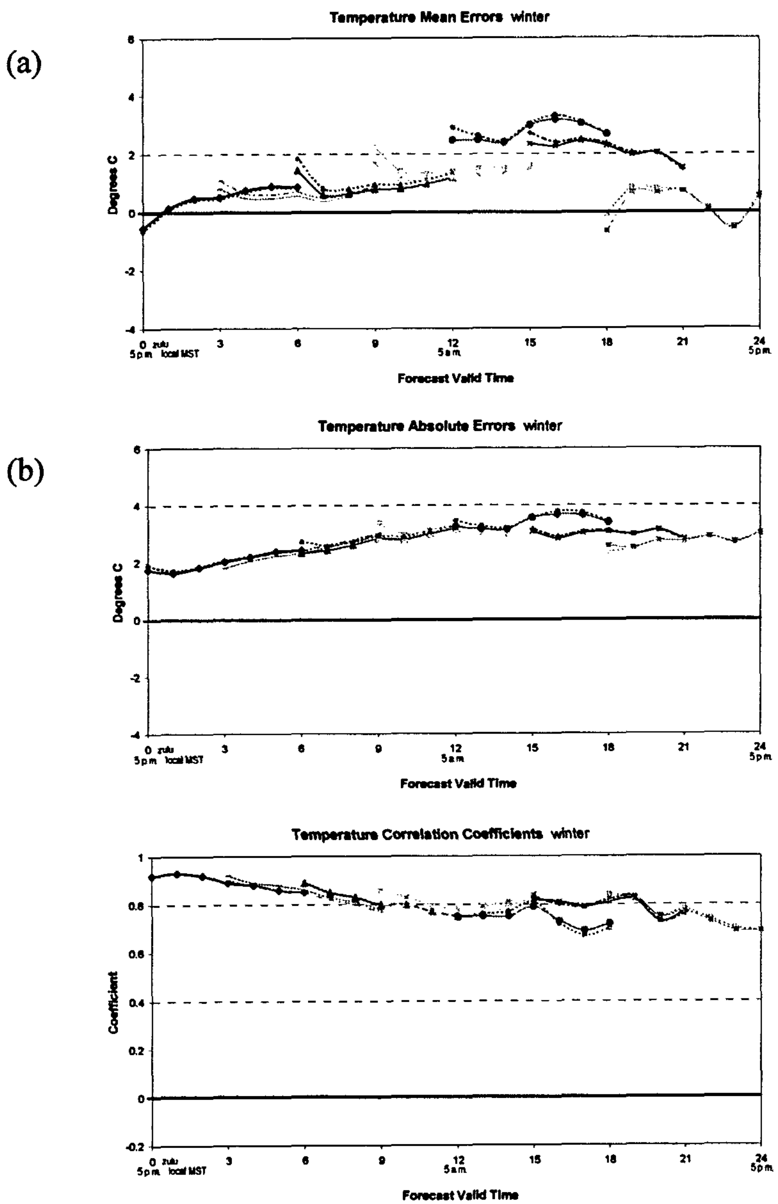


Figure B-1. Temperature (a) mean errors, (b) absolute errors, and (c) correlation coefficients for winter.

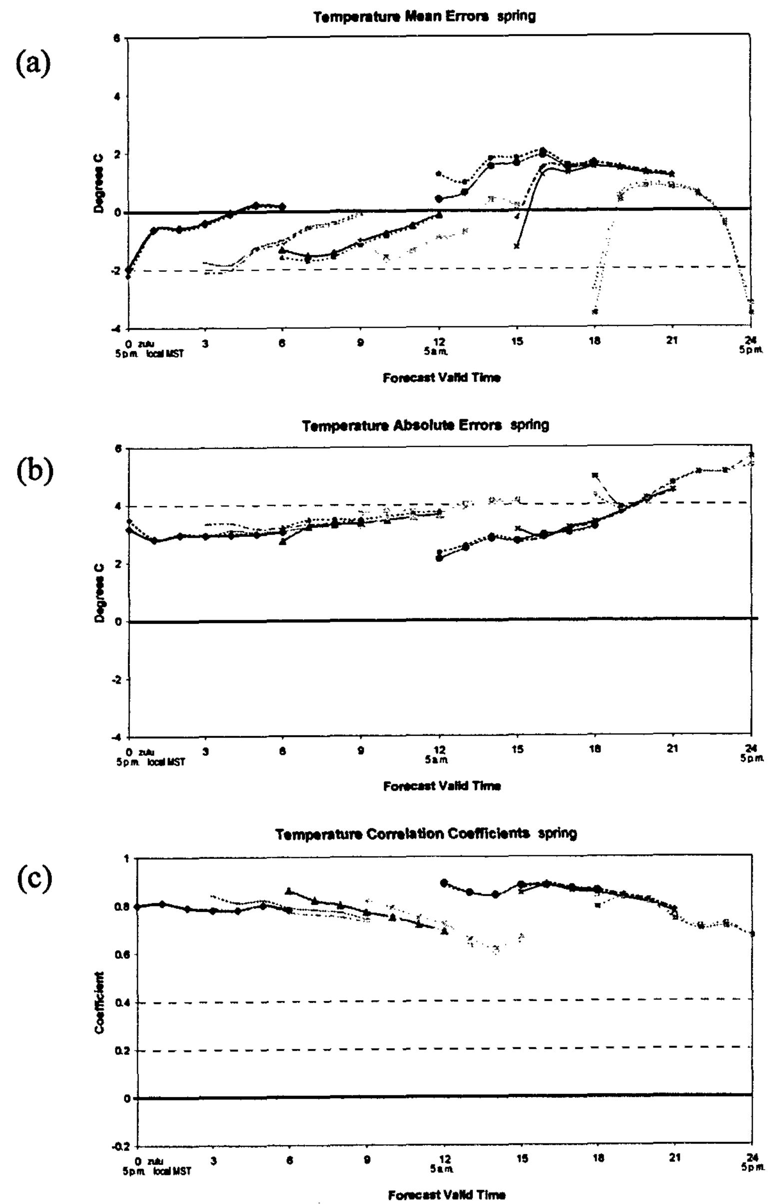


Figure B-2. Temperature (a) mean errors, (b) absolute errors, and (c) correlation coefficients for spring.

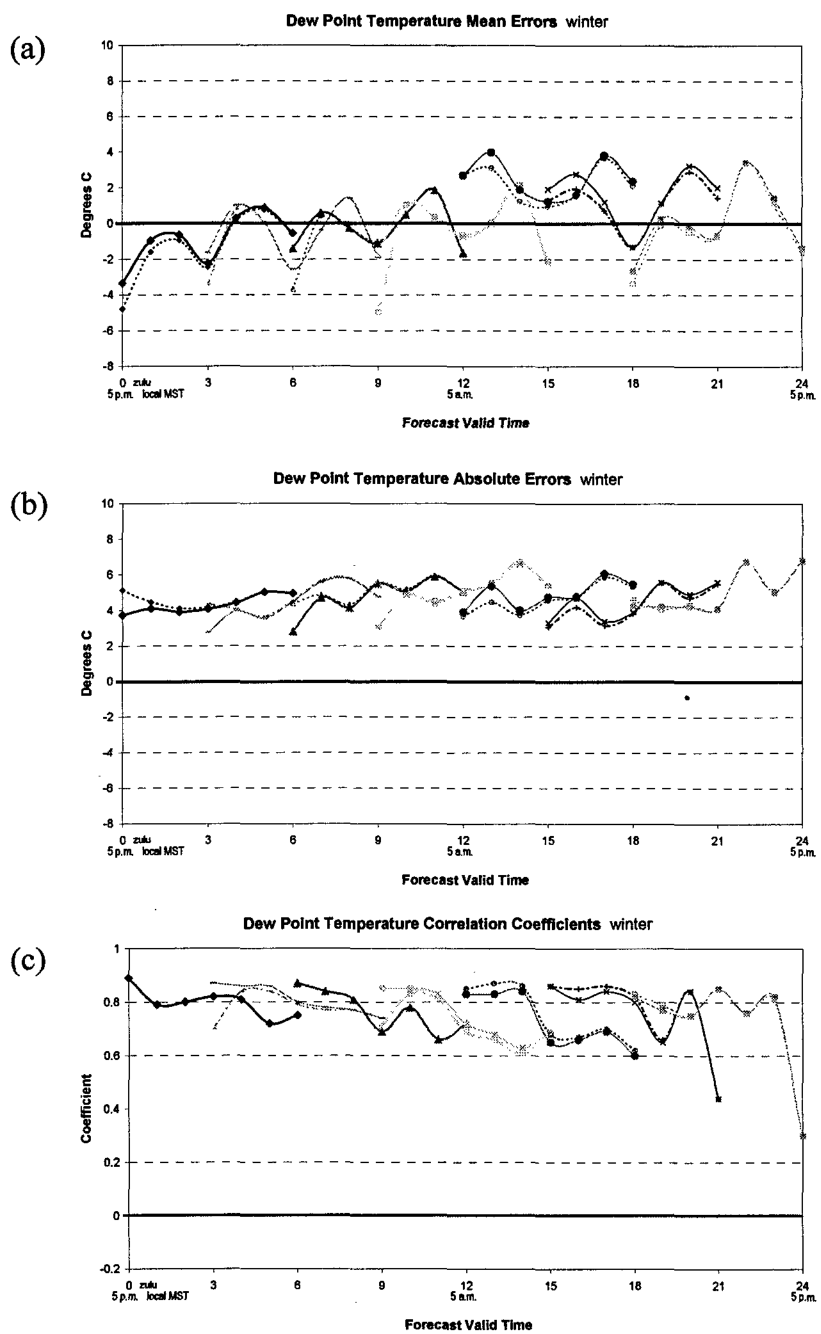


Figure B-3. Dew-point temperature (a) mean errors, (b) absolute errors, and (c) correlation coefficients for winter.

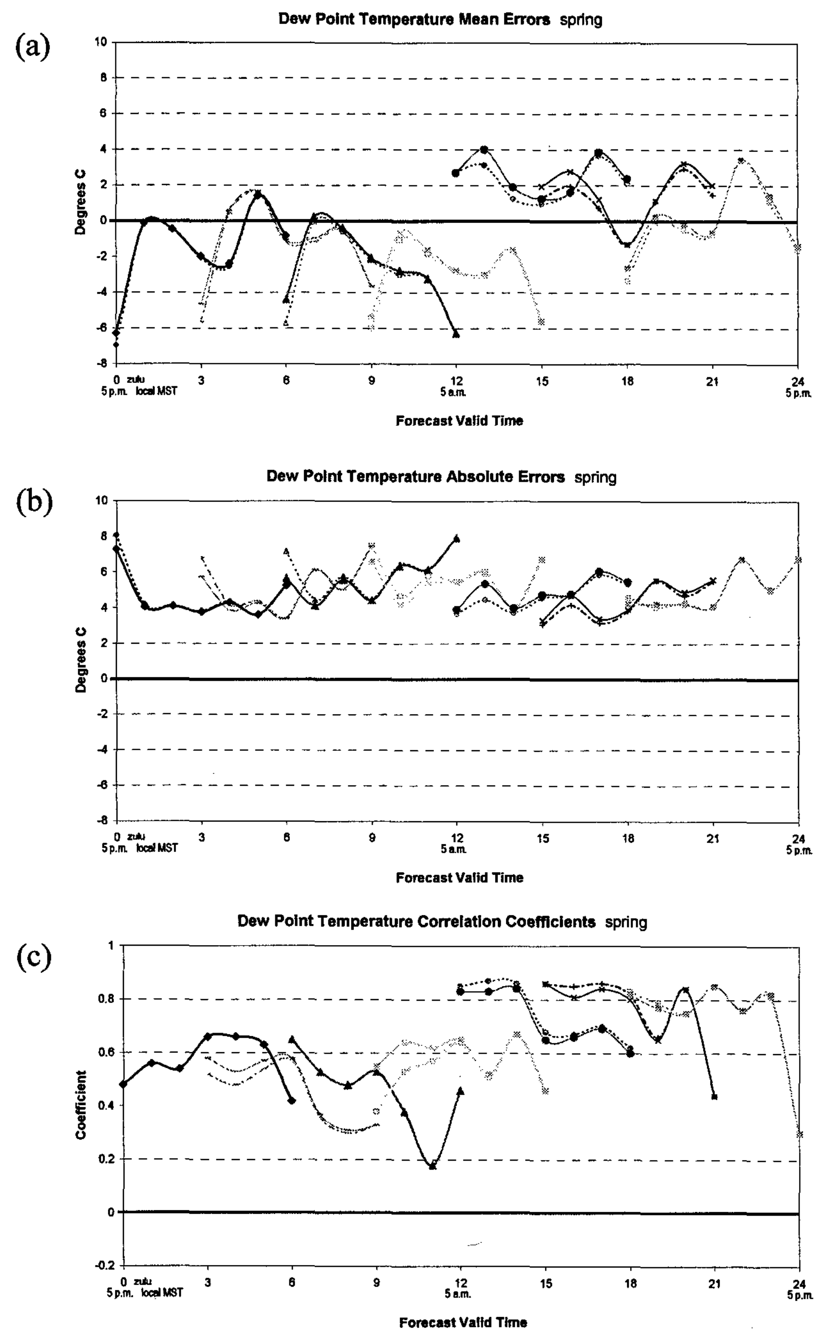


Figure B-4. Dew-point temperature (a) mean errors, (b) absolute errors, and (c) correlation coefficients for spring.

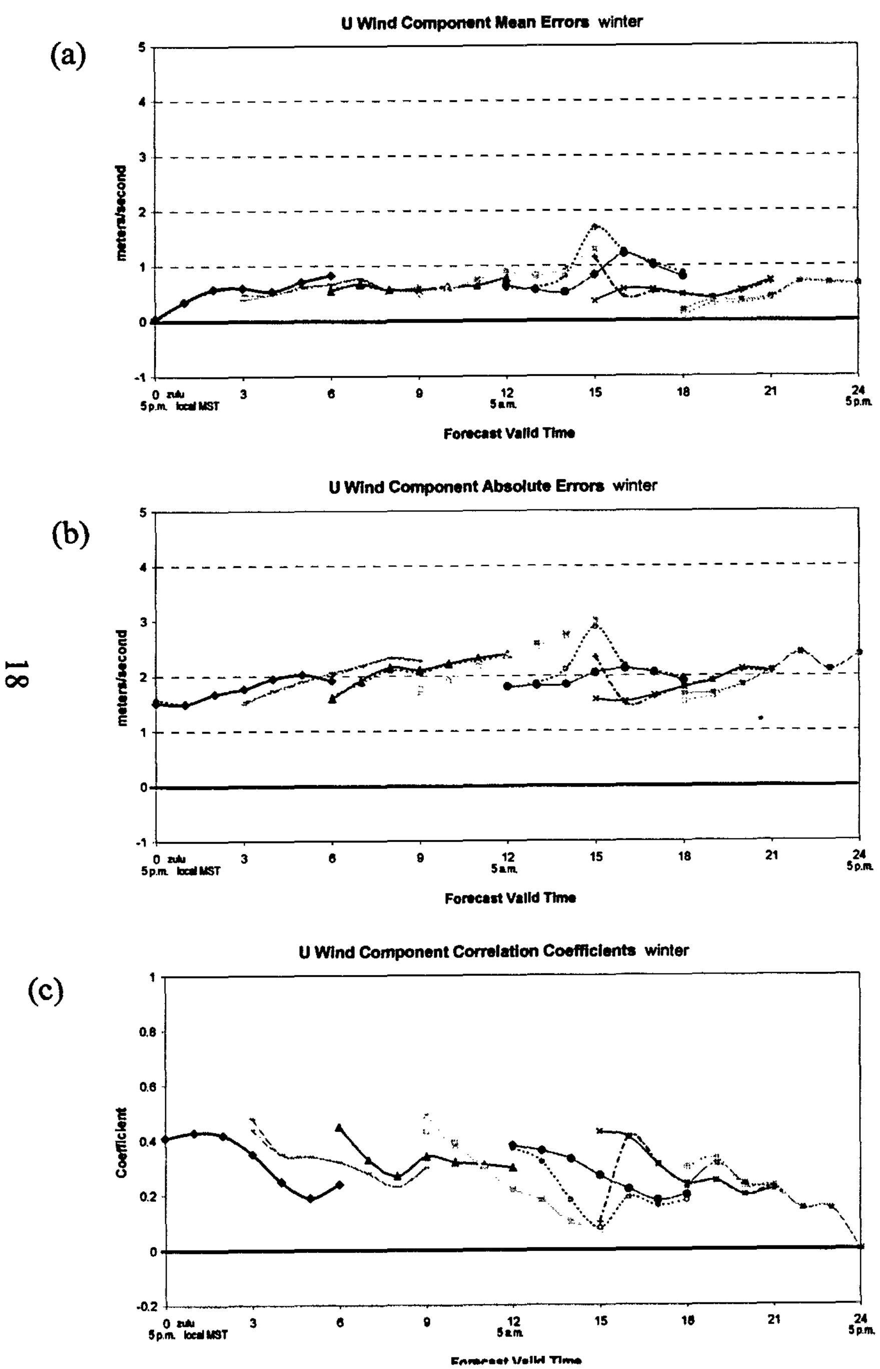


Figure B-5. U wind component (a) mean errors, (b) absolute errors, and (c) correlation coefficients for winter.

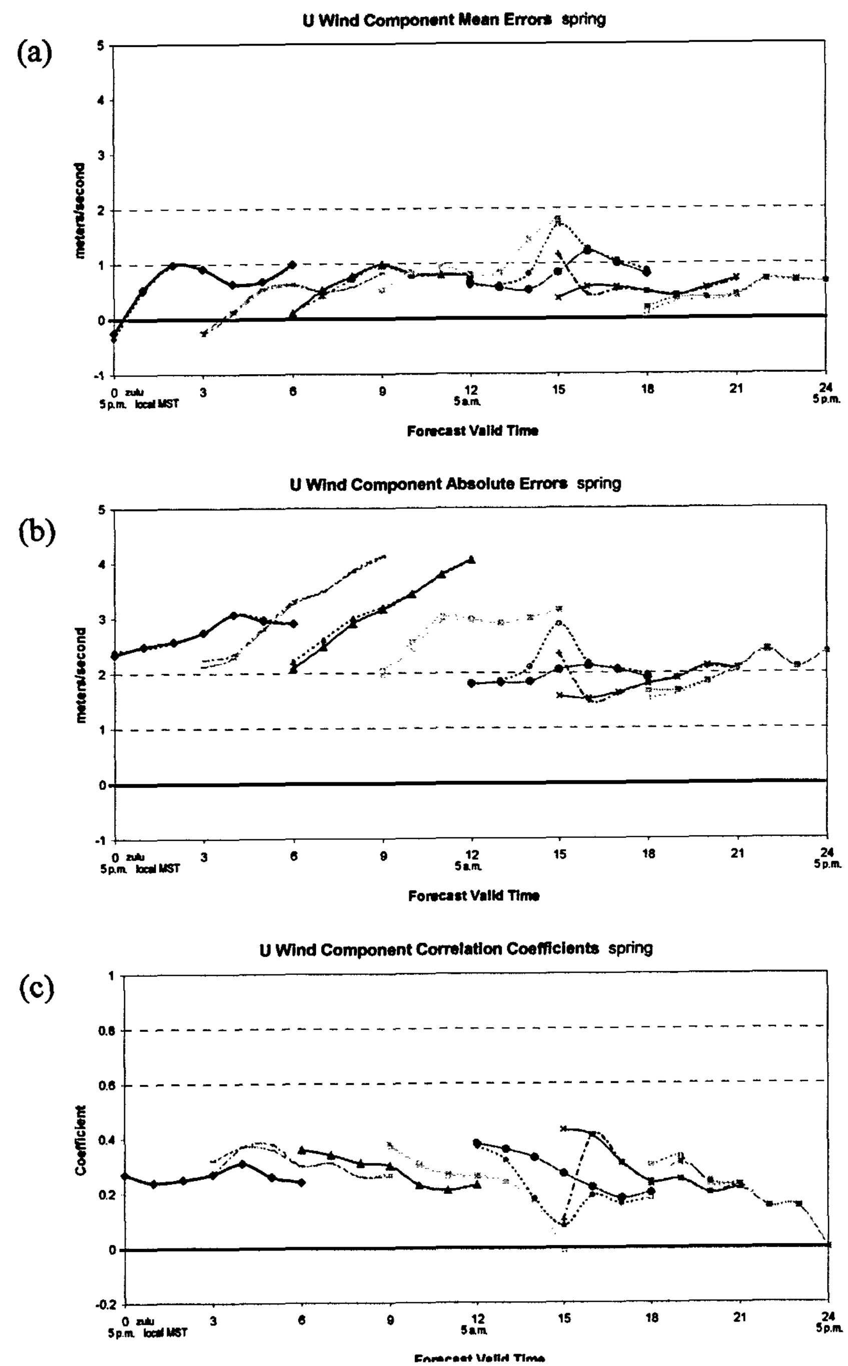


Figure B-6. U wind component (a) mean errors, (b) absolute errors, and (c) correlation coefficients for spring.

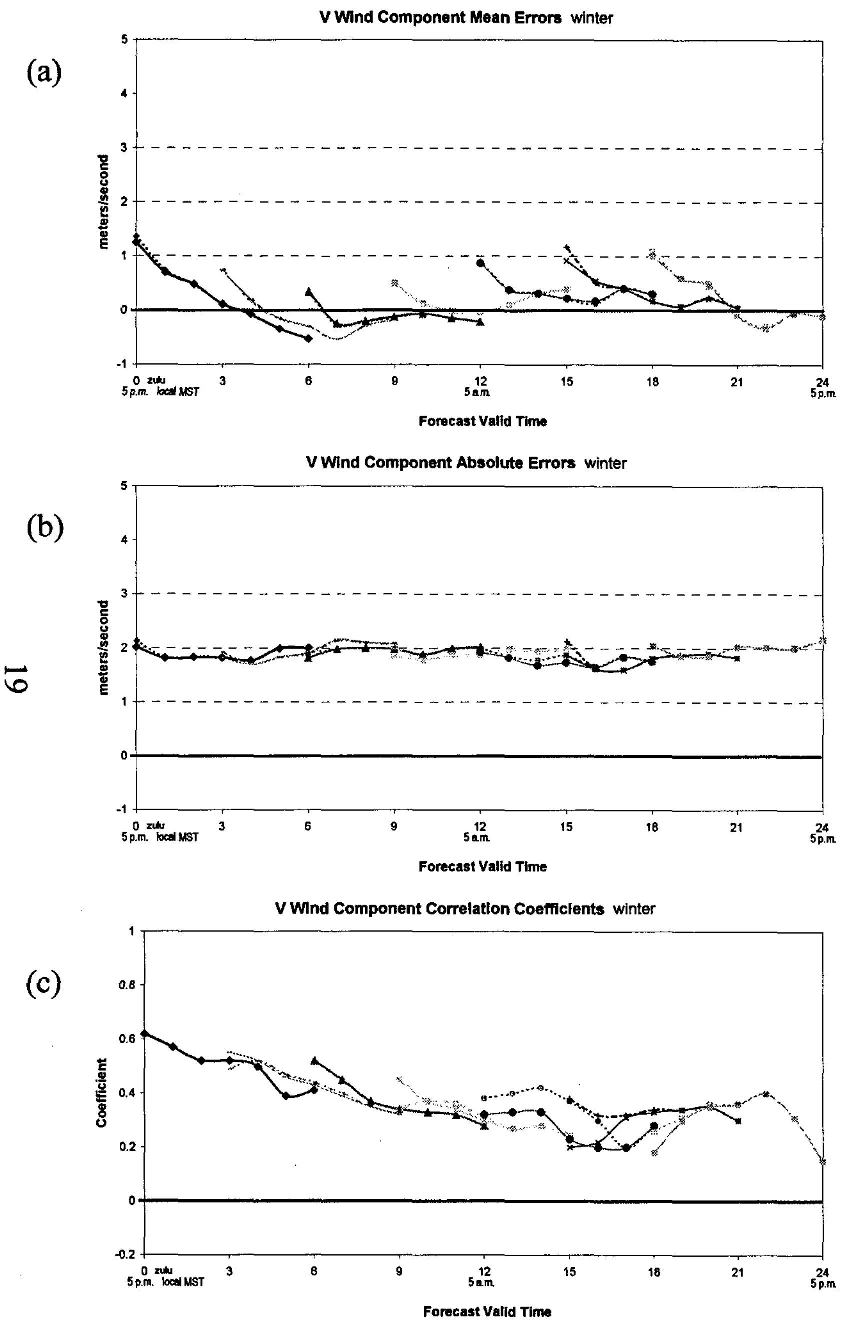


Figure B-7. V wind component (a) mean errors, (b) absolute errors, and (c) correlation coefficients for winter.

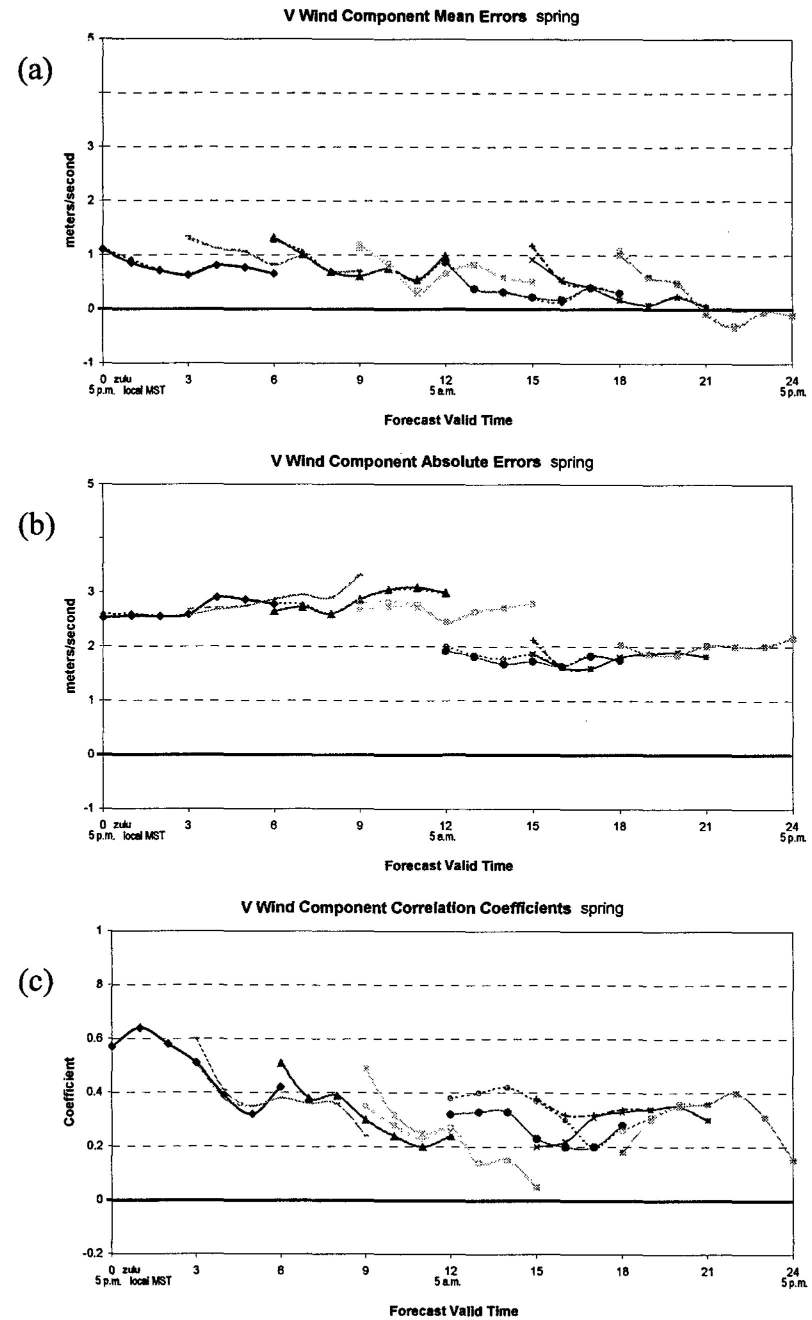


Figure B-8. V wind component (a) mean errors, (b) absolute errors, and (c) correlation coefficients for spring.

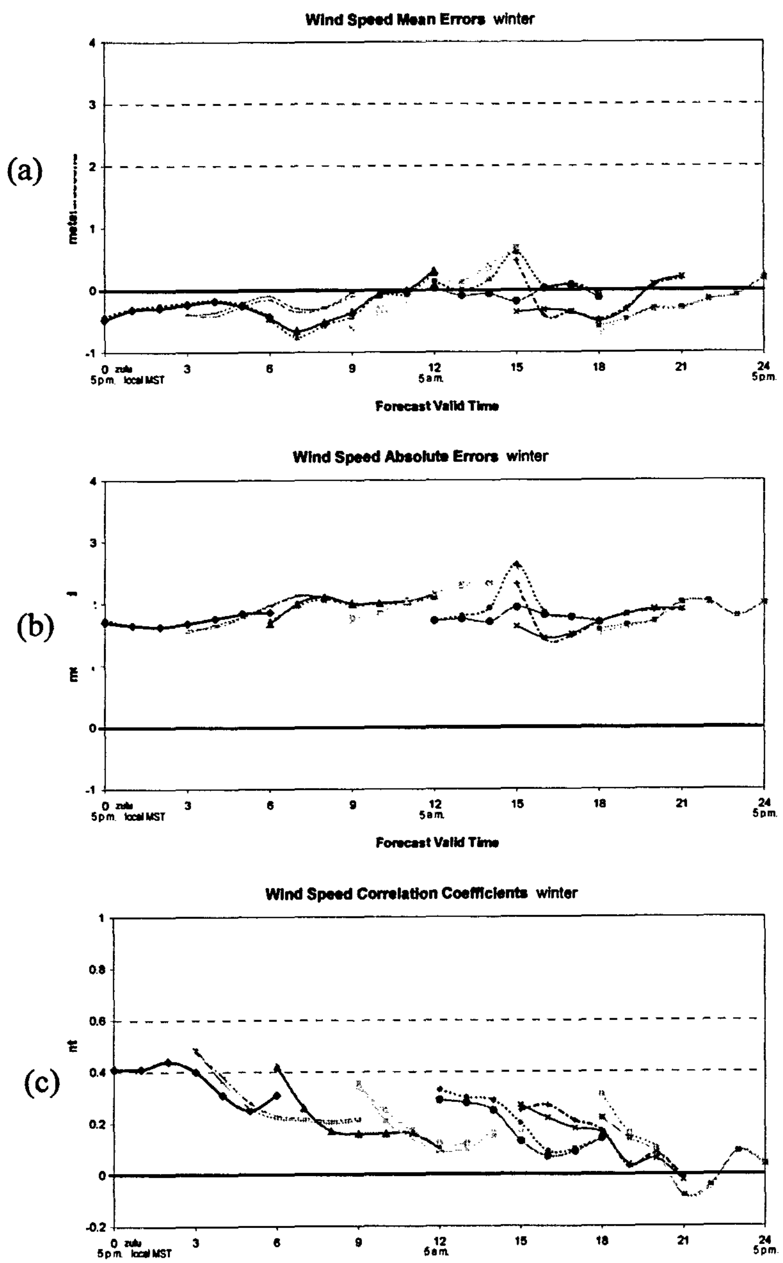


Figure B-9. Wind speed (a) mean errors, (b) absolute errors, and (c) correlation coefficients for winter.

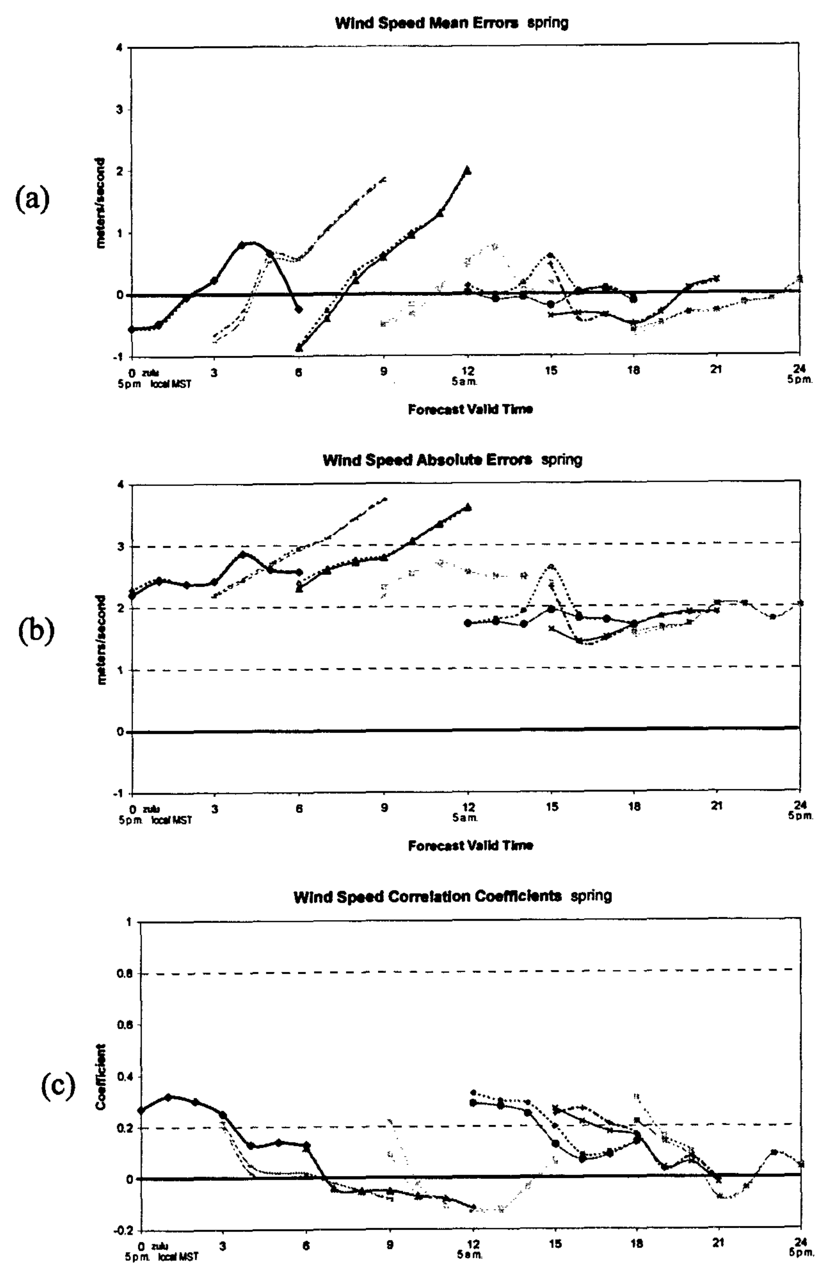


Figure B-10. Wind speed (a) mean errors, (b) absolute errors, and (c) correlation coefficients for spring.

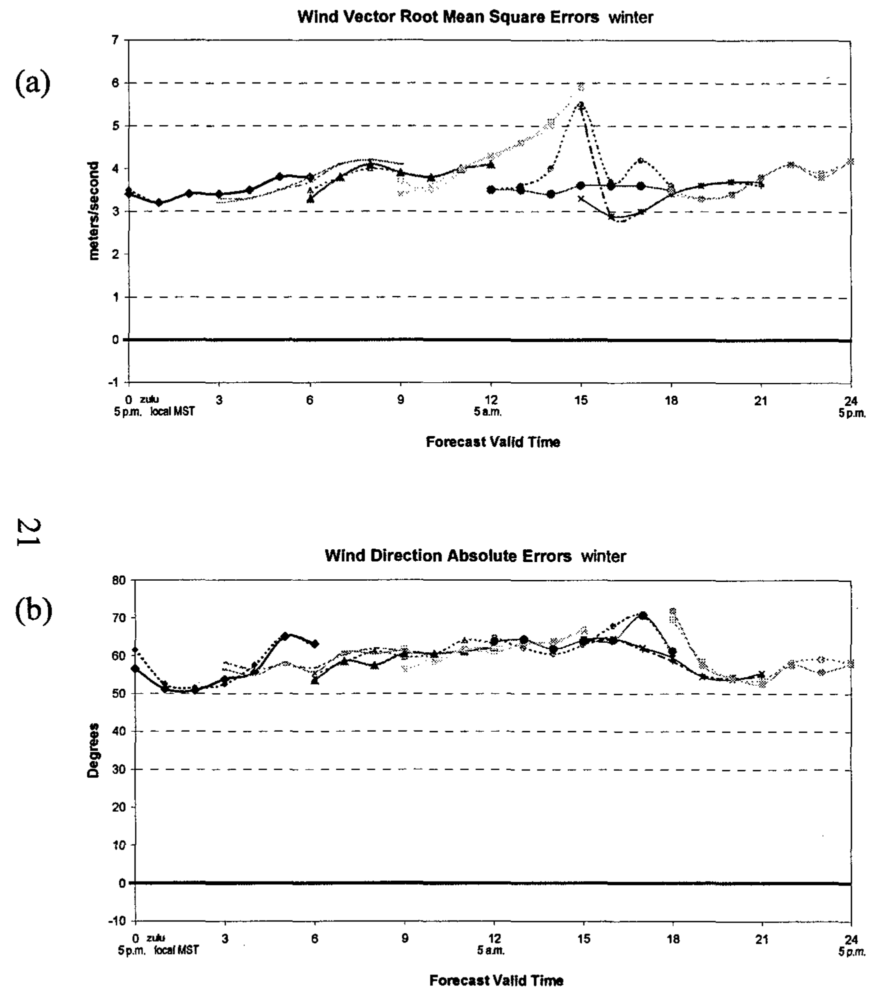


Figure B-11. Wind (a) vector root mean square errors and (b) direction absolute errors for winter.

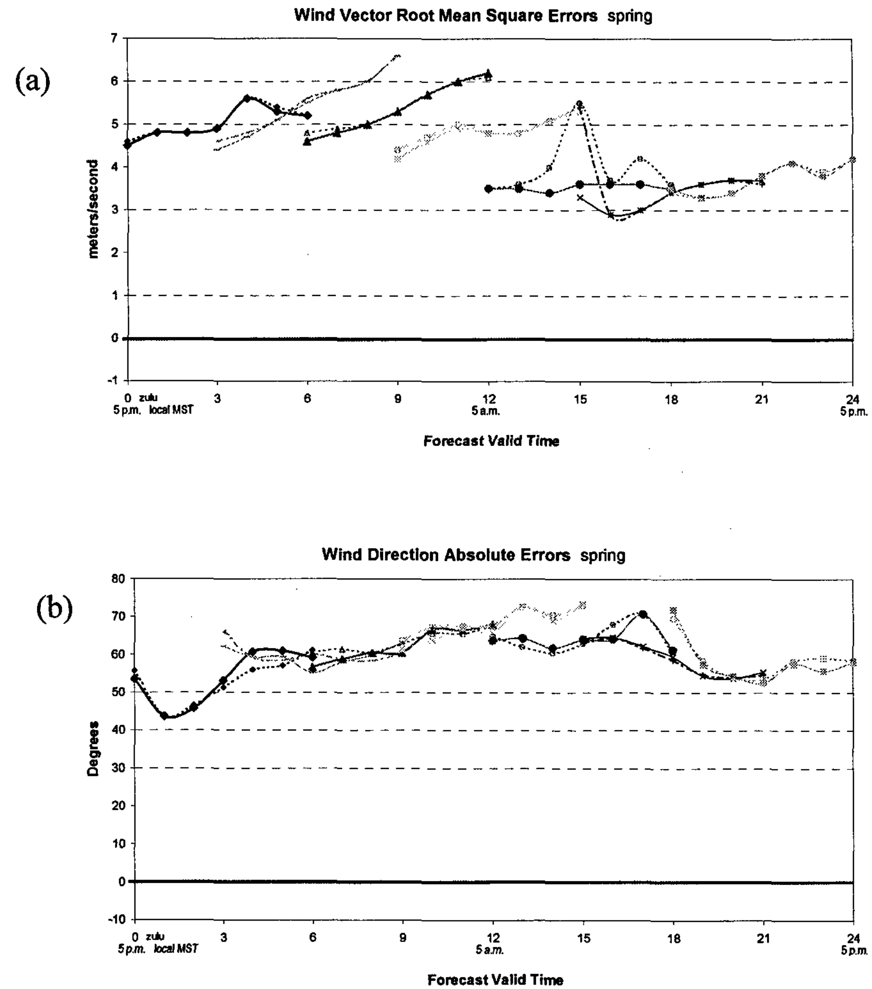


Figure B-12. Wind (a) vector root mean square errors and (b) direction absolute errors for spring.

Appendix C. Differences in Battlescale Forecast Model Results for Model Runs Over Salt Lake City Area

This appendix is part of ARL-TR-2810, U.S. Army Research Laboratory, White Sands Missile Range, NM 88002-5501.

Bar graphs of the difference in Battlescale Forecast Model results between model runs initialized with surface station observation data and with no surface stations over the Salt Lake City area are shown in Figures C-1 through C-8.

The winter charts show the overall results for 32 days, and the spring charts show the overall results for 16 days. Each chart includes seven bars for each forecast hour 0 through 6, with the bars plotted from left to right for initialization times of 00, 03, 06, 09, 12, 15, and 18Z.

Bars above the zero line reflect an improvement in forecast skill based on the incorporation of surface station observations, while bars extending downward from the zero line indicate a decrease in forecast accuracy.

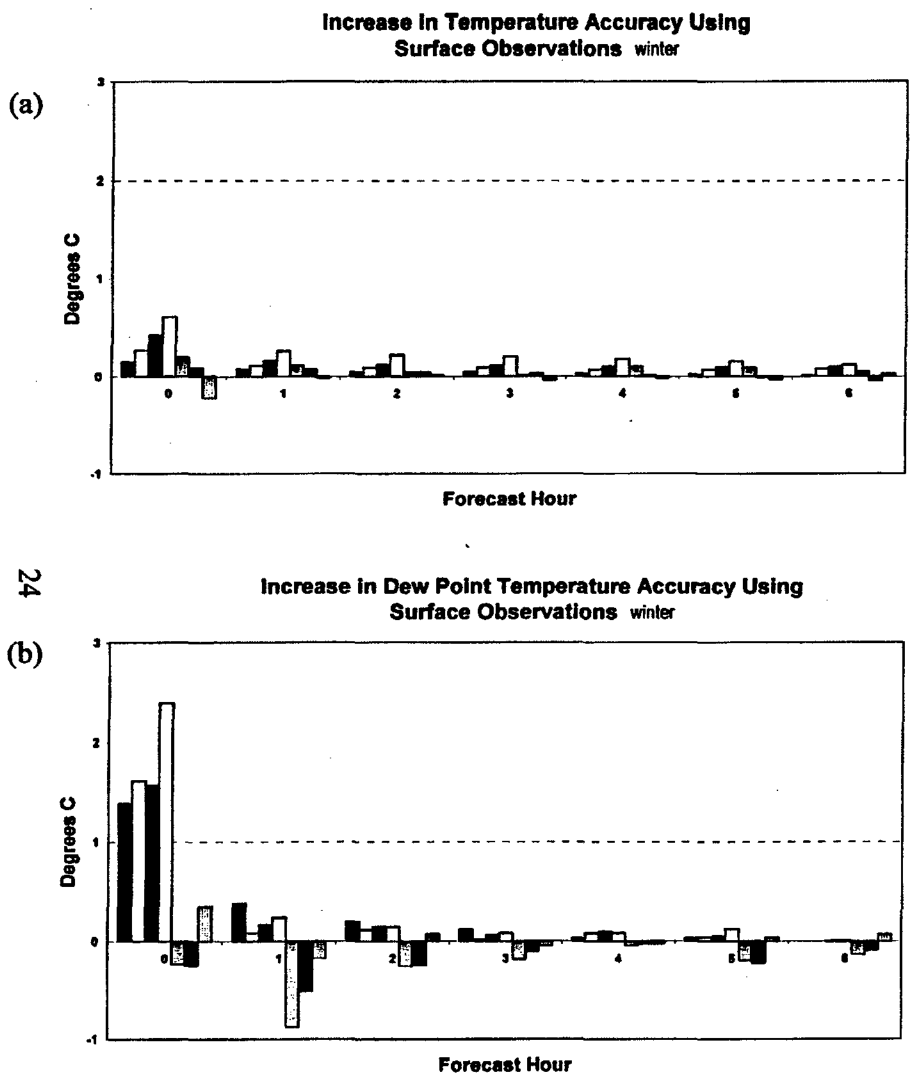


Figure C-1. Increase in (a) temperature and (b) dew-point temperature accuracy using surface observations in winter.

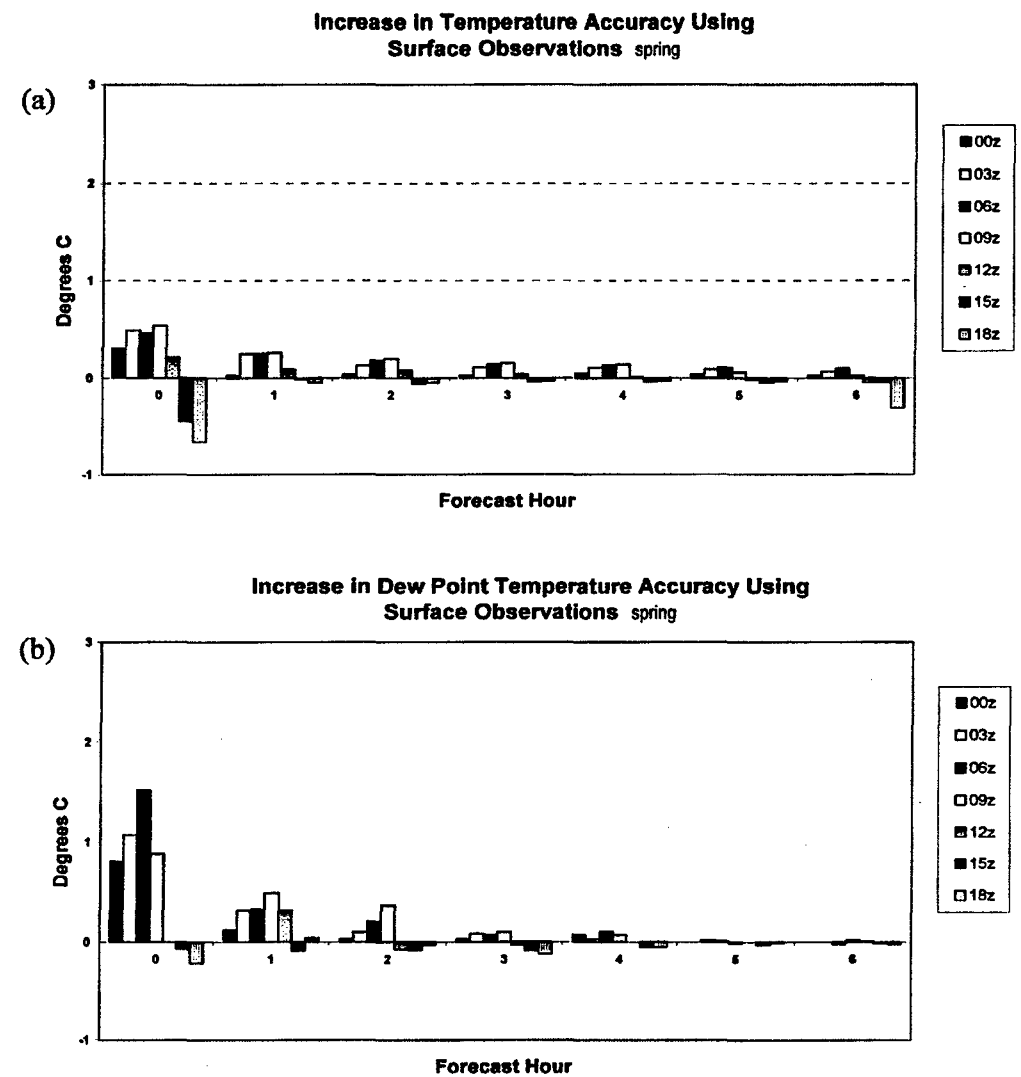


Figure C-2. Increase in (a) temperature and (b) dew-point temperature accuracy using surface observations in spring.

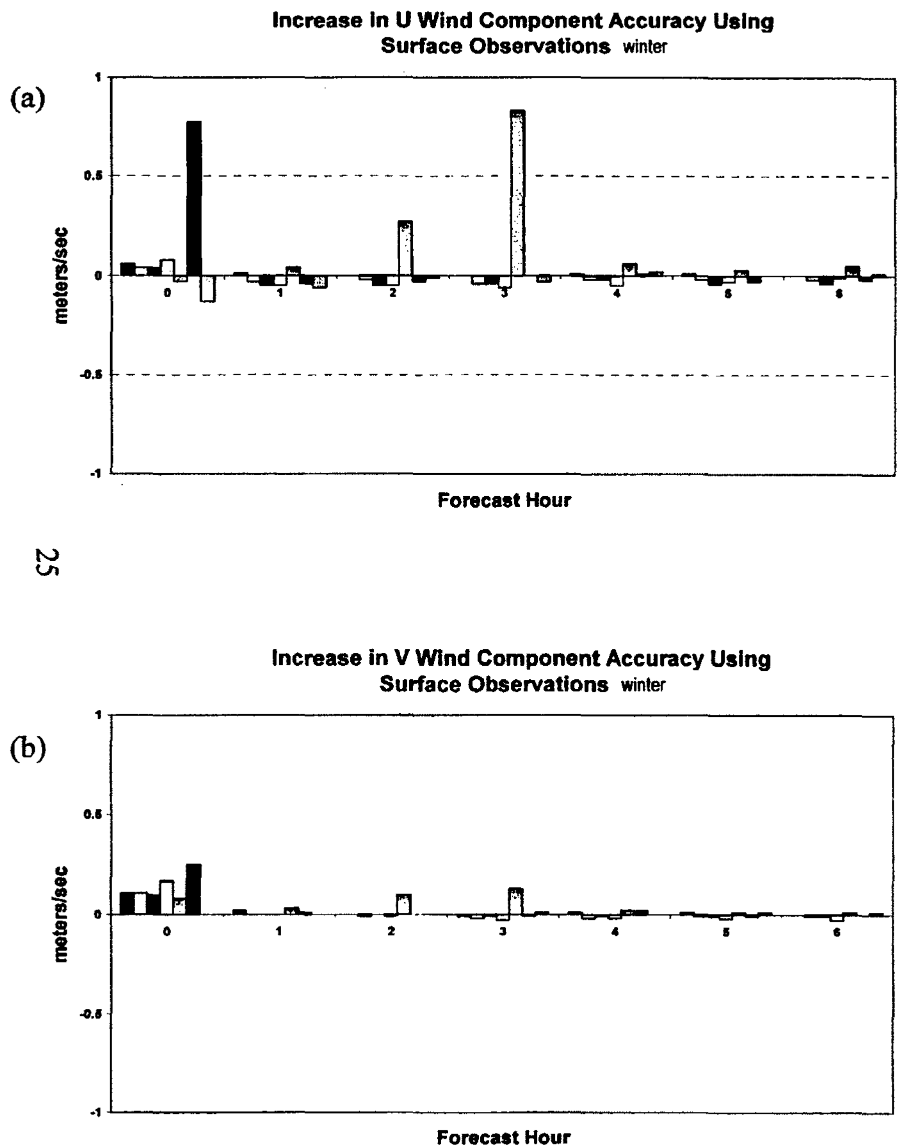


Figure C-3. Increase in (a) U wind and (b) V wind component accuracy using surface observations in winter

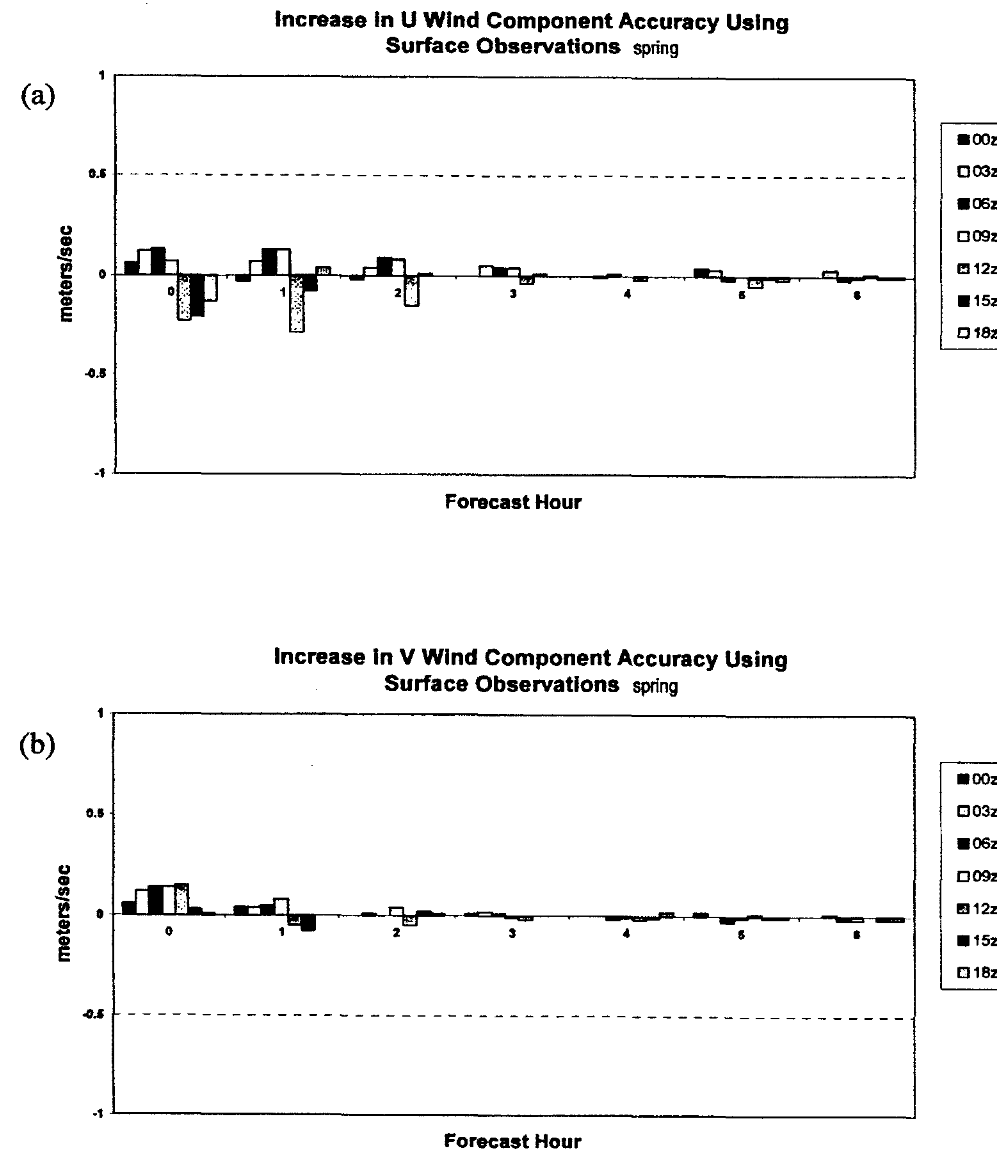
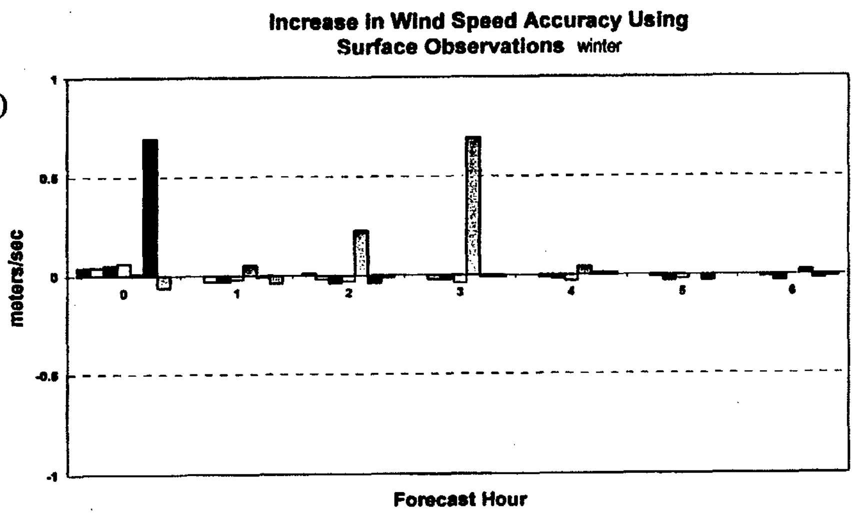


Figure C-4. Increase in (a) U wind and (b) V wind component accuracy using surface observations in spring.

(a)



(b)

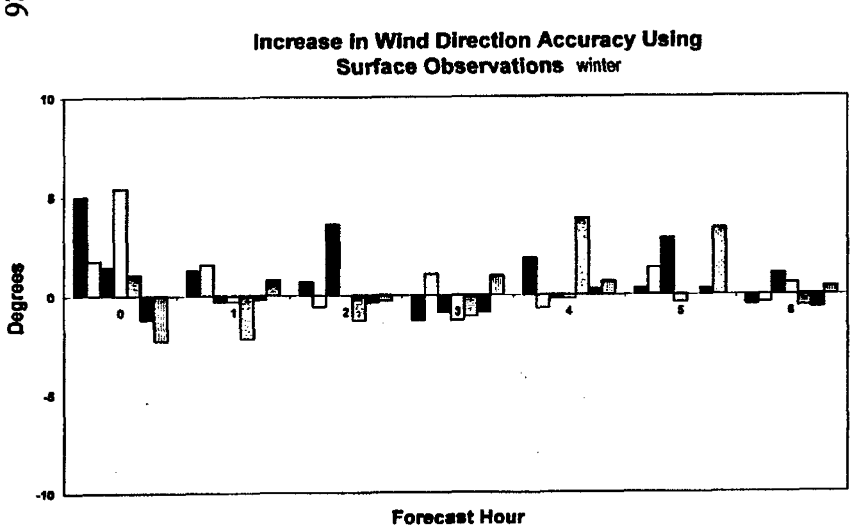
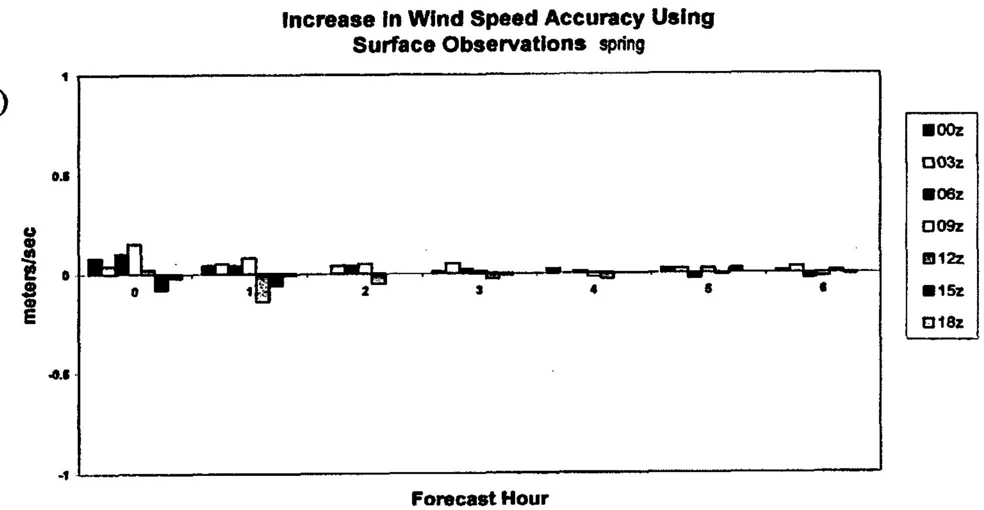


Figure C-5. Increase in (a) wind speed and (b) wind direction accuracy using surface observations in winter.

(a)



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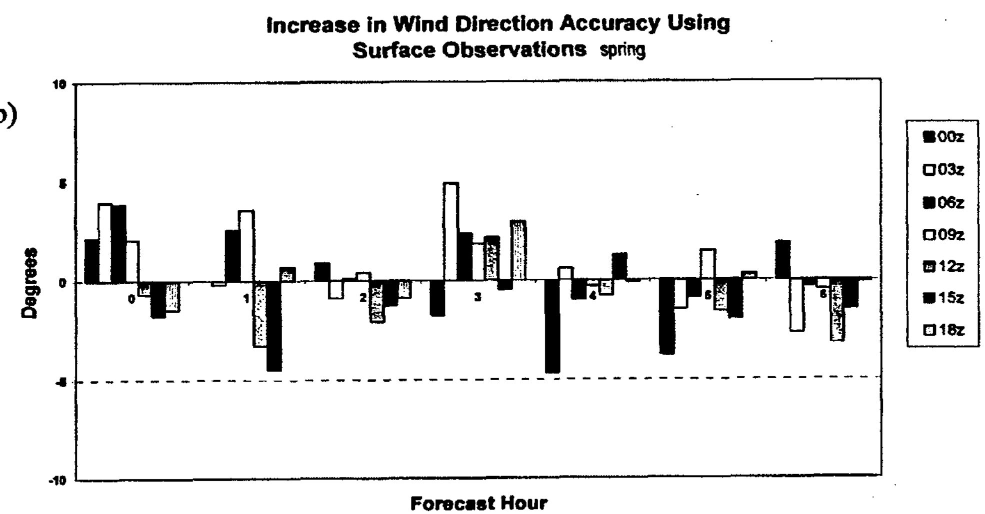

Figure C-6. Increase in (a) wind speed and (b) wind direction accuracy using surface observations in spring.

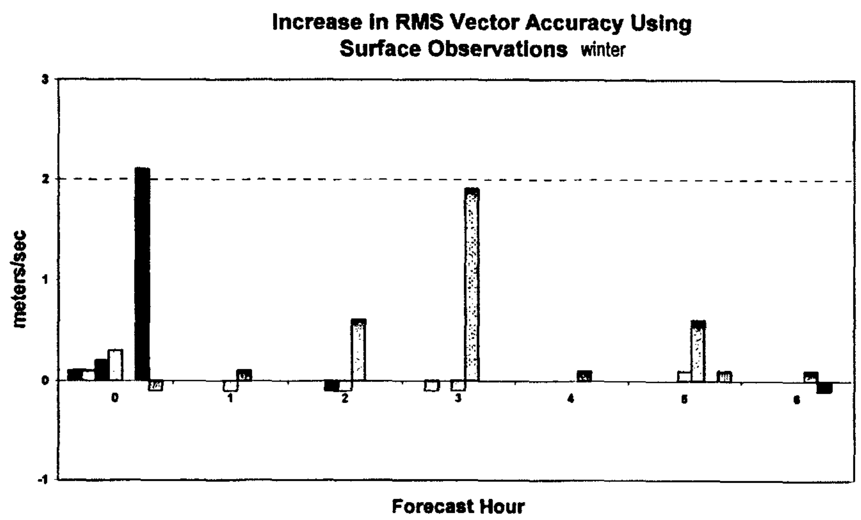

Figure C-7. Increase in RMS vector accuracy using surface observations in winter.

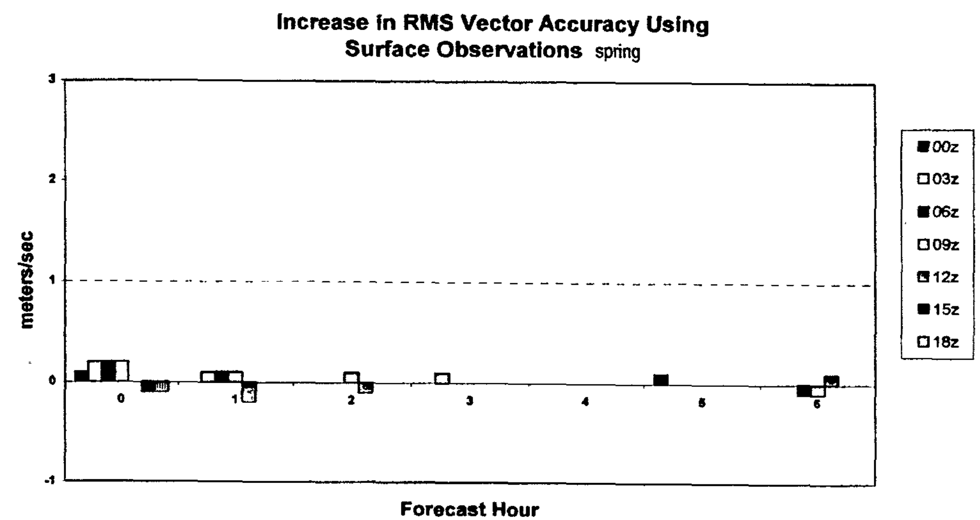

Figure C-8. Increase in RMS vector accuracy using surface observations in spring.

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14. ABSTRACT

The U.S. Army requires accurate short-term weather forecasts in order to optimize the use of personnel and systems in mission execution in a wide variety of locations and conditions. This study investigates the performance of the Battlescale Forecast Model over an area of complex terrain by comparing results of model runs incorporating surface observations from Utah mesonet stations with equivalent model runs made without any surface data.

15. SUBJECT TERMS

BFM, Battlescale Forecast Model, Utah Mesowest, mesonet, surface observation

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